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Is Visualization Usable for Displaying Web Search Results in an Exploratory Search Context?

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Abstract. Information visualization is defined as an interactive and graphic amplifying cognition. Moreover, the field of information retrieval is the original scope of information visualization. Nevertheless, many problems remain. The exploratory research information is presented as a task context conducive to the use of visualization. The research aims to identify the dynamic and interactive graphics that use a search visual interface (versus text), and the gain in terms of usability compared to strategic and tactical requirements of the task of exploratory search on the Web exploratory type. The theoretical, conceptual and methodological framework is presented.

Keywords: information visualization, exploratory search, clustering, usability.

1 Introduction

The search engine has established itself as an almost exclusive means of searching and browsing the web, and its technical and algorithmic performance is widely recognized. However, the “query-result” paradigm has several interactivity limitations and is only appropriate for a limited spectrum of search taxonomies [1]. Indeed, Google’s search interface is considered adequate only for 17% of the searches it performs [2]. Considering the broad spectrum of information search taxonomies [2], [3] and information behaviours [4], a new current in scientific research has emerged in the past years that focuses on the interaction between the user and the system rather than the individual analysis of those entities [5], [6]. Indeed, the searching interface has become a focal point for researchers [7]–[10]. For exploratory searching in particular [11], new interfaces are being developed for the benefit of relevant exploratory tactics and strategies [9]. In this respect, visualization of search results appears as a promising device for the information seeking process.

Due to the double interactive and visual-perceptual process it entails [12], [13], visualization is characterized by its tendency to amplify the cognitive faculties deployed by the user for knowledge building, analysis and learning processes [14]. Nevertheless, in the field of information retrieval, the evidence of cognitive amplification is yet to be demonstrated within the exploratory search context.

Thus, our research stands on the crossroads of several challenges. Firstly, although it is known that visualising information aids memorisation and analysis of information

in general, the means of implementing visually structured search results remains to be determined. Secondly, the new interactive modalities required by the exploratory research process introduce additional dimensions which extend beyond the reach of typical recall and precision metrics. Thirdly, it has not yet been verified that, when compared to other interfaces designed for exploratory search, visual and interactive presentation of results leads to a clear gain over a textual list-based presentation, based on the same clustering algorithm.

The goal of this research is to assess the gain in terms of usability, from the user's point of view, of exploring search results through a visual layout (as opposed to a textual layout) when performing exploratory searches on the Web. Increasing usability of an interface means reducing the cognitive load associated with its use and simplifying the cognitive, affective and physical processes related to the final task of the user.

Because we believe that interactive visualization reduces cognitive load associated with information treatment processes required by cognitive strategies and research tactics in the context of exploratory information search, we assert that it can benefit the user's investigation and discovery processes beyond the known positive effects of clustered results [15].

Our research aims to evaluate the usability of visualization in the context of exploratory information search on the web. To accomplish this, we wish, through heuristic analysis and controlled experimentation by simulating tasks related to exploratory information search, to:

- Identify the graphical and interactive functional factors of visualization that have an impact on the process of exploratory information searching
- Correlate visualization and exploratory information searching in terms of usability on the basis of identifiable search strategies and interactive views, according to either the user's proficiency in a particular field of knowledge or his expertise in information searching
- Through interaction between the user and the context-related visualization device, define what represents a gain or an obstacle in the process of exploratory information search, in particular with respect to the user's own strategies and tactics

2 Literature Review

2.1 Exploratory Search

Marchionini [11] and White and Roth [16] have modeled the exploratory search process by providing perspective on the iterative and non-linear dynamics between different cognitive strategies and associated search tactics.

This model highlights interactions between different strategies and their associated tactics. Among exploratory search tactics, several behavioural information search models, such as the «berry-picking model» by Bates [17], the «sense-making model» by Dervin [18], and «information foraging» by Pirolli et Card [19] can be recognized.

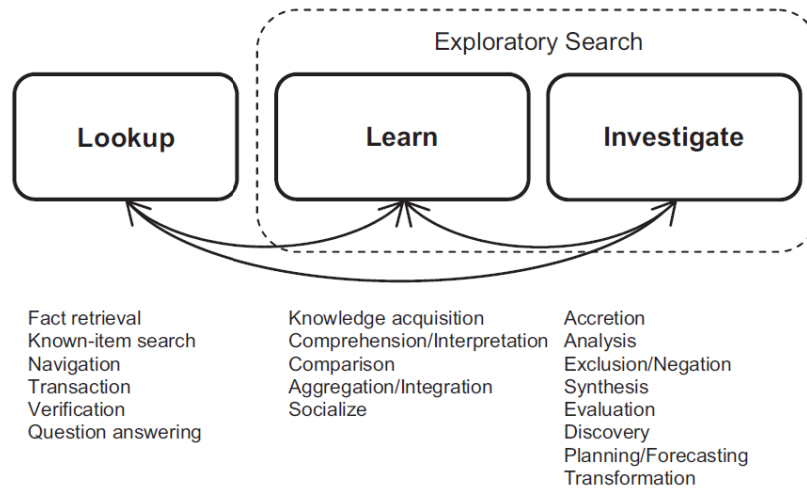


Fig. 1. Exploratory search model based on Marchionini [11] (Source: White and Roth [16] p. 14, reprinted with permission)

The main learning strategy partly reminds us of Kulthau's more general process [20], [21] which consists in reducing cognitive and affective uncertainties by providing new information to address a gap or a weakness in the state of knowledge.

The process of exploratory information, aimed explicitly at the acquisition of new knowledge, is a typical example of this type of process [1]. Thus, with respect to these cognitive challenges, the « query-response » paradigm that dominates the search engine environment is considered inefficient, if not detrimental.

Since 2006, an increasing number of scientific meetings (EESS2006 ; ESI2007; HCIR2010; WISI2010) are being organized to discuss the main challenges associated with exploratory information search: interactivity and evaluation. Two types of interface are emerging to support exploratory information search: faceted interfaces such as mSpace [22] and visual interfaces such as Carrot2Search [23].

2.2 Search Results Visualization

The visualization of search results is a device for visualising information that consists in displaying the results that match a user's query in a graphical and dynamic manner, and proposing a device that facilitates navigation within these results through interactive views.

The visualization of information (fig 2) is an interactive device acting as an external cognitive aid [24]. Graphical and interactive representation of results aims at revealing dominant themes or informational motives that characterize the results, in the same manner that performing a mathematical calculation in writing relieves the cognitive load of mental calculation on the memory.

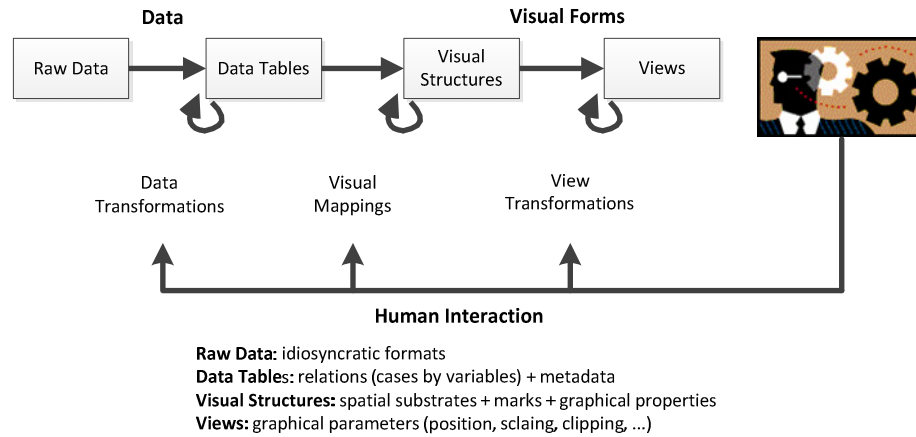


Fig. 2. Reference model for information visualization process (Source: Card, Mackinlay et Shneiderman [14] p. 17 reprinted with permission)

To accomplish this, visualization of search results is designed with the aid of clustering algorithms originating from the field of text searching. The web has and will continue to bring numerous challenges regarding the structuring of search results [23]. To this day, unsupervised clustering algorithms (Suffix Tree Clustering, k-means) can be adapted to the dynamics, the heterogeneity and the size of the web. Moreover, this structuring process, with or without downstream visualization, is known to facilitate investigation and discovery within large masses of textual material. As a result of these properties, visualization helps the knowledge crystallization process.

This crystallization process (fig 3) calls for tactics and strategies that are similar to those of exploratory information search. Interactive viewing allows direct manipulation of the graphic representation in order to enable analytical and investigatory processing of results, thus providing an insight into the state of knowledge available on the web on a particular subject.

However, beneath the surface of visualization's generic principles, the application of visualization in the environment of search results remains problematic. Some openly criticize the use of this device on search results given the textual nature of information [8]. In the commercial sector, two important players have been forced to cease their operations as visual meta-search engines: Kartoo and Grokker. On several occasions, in a general context or with reference to information search, researchers [25]–[27] report similar findings concerning visualization: challenges include a lack of understanding of the cognitive processes involved, scalability issues associated with the variable size of the information mass to be processed, and difficulties related to categorization and labelling of search results [23].

On a more fundamental level, a major obstacle to the establishment of this device is the absence of an authoritative evaluation method [28]. Although the theoretical principle of cognitive amplification is agreed upon, its application is based on a multidimensional analysis, where a deep understanding of the interaction between the user and the system is essential. The question is then: how to evaluate the impact of interactive views on the user experience of information seeking process?

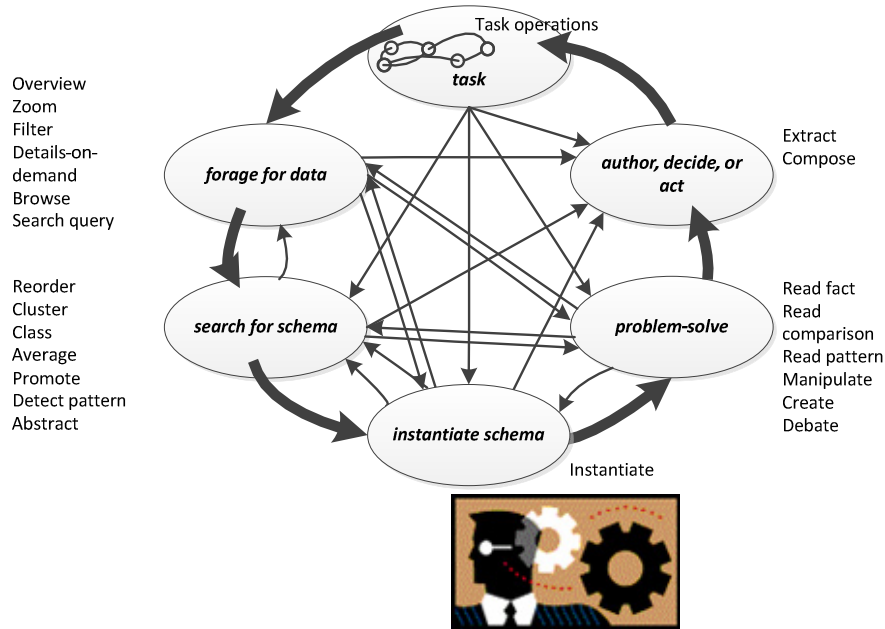


Fig. 3. Knowledge crystallization during information visualization process (Source: Card, Mackinlay et Shneiderman [14] reprinted with permission)

2.3 Evaluation of Search Results Visualization

The evaluation of a system aims to assess its capacity to satisfy a user according to chosen criteria [29]. In the fields of both scientific research and innovation, evaluation serves the role of a barometer that is able to validate the quality of a system with respect to different criteria, such as performance, satisfaction, usefulness or usability. The objective, the context, the task at hand and the stage of maturity of the system are all relevant criteria for selecting a scenario and an evaluative approach [30]. Traditionally, information retrieval systems were evaluated through performance, a system-centered criterion, by measuring the system's recall and precision rates [31]. The interdependency between the interactions generated by the system's use and the information seeking process performed by the user makes placing the user at the core of the evaluation process essential.

Evaluating the visualization of search results will address the requirements of the task at hand as well as those of the exploratory search and of the visualization process. To perform this assessment, we aim to take advantage of the shared nature of visualization and information seeking processes, as summarized by Zhang [32], and to gauge the added value of the visualization device. Several evaluation methods are in use, although none have earned general recognition [33]. To evaluate the user experience with respect to a given task, it is recommended to assess device usability [30].

In practice, it appears that few usability studies have been conducted to this date [25], [34], [35] and that controlled, user-centric experiments are currently the preferred

approach. The latter offer the advantage of precise and generalizable results [28]. Most are focused on method evaluation and measuring the impacts of individual characteristics (gender, spatial abilities, cognitive style, associative memory). However, the heterogeneity of chosen measures, tasks and visualizations thwarts the process of comparing results [36]. In addition, some case studies and longitudinal studies have been performed; their results are very detailed but remain hardly generalizable. Moreover, although not pertaining specifically to the evaluation of visualization of search results, the usability evaluation framework designed by Wilson [37] establishes measures that allow the assessment of interactive features according to the strategies of exploratory research. The last method for evaluating user experience considered in this research focuses on the insight gained by the user from the visualization of the presented information, rather than on the device and its components. North [38] mentions that these two evaluations are not in opposition but that they are, on the contrary, rather complementary. Indeed, Rester and Pohl's [39] study on the evaluation of a visualization device designed to facilitate exploratory research processes confirms this statement.

3 General Study Design

Our research seeks to evaluate, in terms of usability, the added value of the visualization of search results in the context of exploratory information search on the web. The main hypothesis of this research is that interactive views support the tactics and strategies related to information searching.

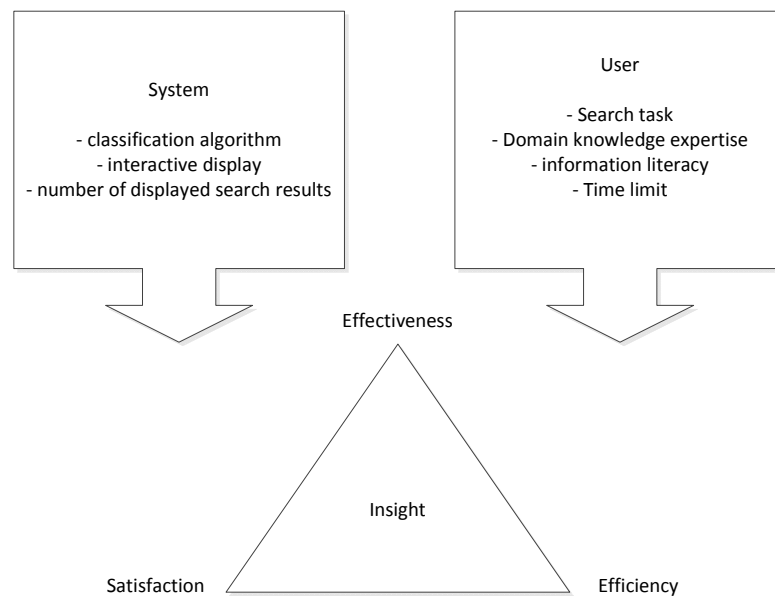


Fig. 4. Design of the usability evaluation of search results visualization

The evaluation framework (fig 4) covers two phases and calls for two experimental exercises. The first phase aims to evaluate the usability of the device through a two-stage process. During the first stage, the interface is inspected for a first time according to heuristics [40]. The second stage implies controlled testing of the interface by two types of users (experts in information search or experts in a field of knowledge) by simulating an exploratory information research task.

In practice, the objective of evaluating the usability of a visualization device for search results is to demonstrate that the different system components (indexing, organization, interactive display) are processing the information required to accomplish the user's task in an efficient, effective and satisfactory manner. Thus, an interface with a high degree of usability is a system that helps reduce the user's cognitive load to a minimum. Several objectives are pursued by evaluating the relative usability of a visualization device. Firstly, the limitations and weaknesses associated with the visualization device within and outside of the information search context will be identified. Secondly, the interface features that are used to support research strategies and tactics will be compared in terms of usability.

The second phase is of a qualitative and investigatory nature. Its aim is to assess the insights the user receives through the use of a visualization device, according to the chosen tactics and strategies of exploratory information search.

The system selected for this experiment is the Carrot2Search engine (fig 5). This system features a textual as well as a visual interface, is based on high-performance automatic classification algorithms and defines itself as open software for academic purposes.

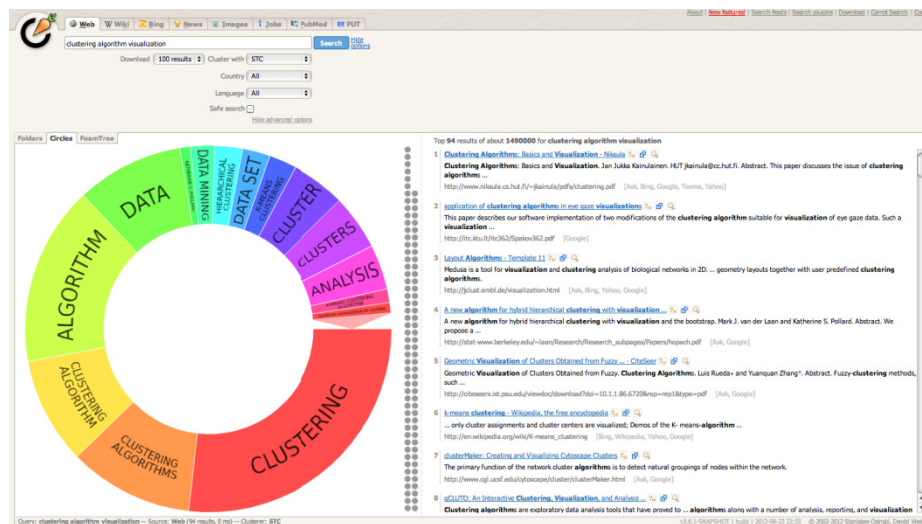


Fig. 5. Example of visual clustered search results interface with the STC algorithm from Carrot2search engine

Several types of expertise are tested simultaneously to shed light on the various factors known to have an impact on the skills required for the use of information visualization and exploratory information search on the web. Thus, the proposed heuristic analysis will be performed by information visualization experts. The experimental phase calls for two types of users: 15 volunteer users that have demonstrated their proficiency in information handling by successfully completing the Information Search coursework at the Library Sciences School of the University of Montreal, as well as 15 users that have proven skills in a field of knowledge related to the task of information search.

4 Conclusion

In theory, visualization constitutes an external cognitive aid. It supports memorisation and the processes of analysis and investigation by highlighting patterns and relationships between various pieces of information. These cognitive properties appear to assist the strategies and tactics required by exploratory information search. This research aims to evaluate, in terms of usability, the added value of a device designed for the visualization of search results within an appropriate context. We hope this work will make three types of contribution to evolving knowledge. Theoretically, we seek empirical evidence confirming the cognitive benefits of visualization in the context of exploratory information search. Methodologically, we aspire to devise effective qualitative metrics for evaluating the visual interface for exploratory information search. Lastly, we wish to formulate practical recommendations for successfully integrating visualization into information search interfaces.

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